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PRESENTATION ABOUT RESULTS PRODUCED AFTER MEASURING PAL-ITF BEAM DIAGNOSTIC INSTRUMENTS*

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Abstract

Pohang Accelerator Laboratory (PAL) built a PAL-ITF at the end of 2012 to successfully complete PAL-XFEL in 2015. The PAL-ITF is equipped with various kinds of diagnostic equipment to produce high-quality electron bunches. An ICT and a Turbo-ICT were installed in the PAL-ITF. A Faraday Cup (FC) is installed at the end of the linear accelerator. These days, the quantity of electric charge occasionally is measured using a BPM Sum value.

This paper focuses on the processes and results of electric charge quantity measurements using ICT, Turbo-ICT, FC and BPM. The PAL-ITF is equipped with Stripline-BPM. It is important to find a way to minimize measurement errors that can appear in the process of installing or measuring the BPM. For this, PAL-ITF separately measured the BPM electrode sensitivity and minimized BPM measurement errors through generally calibrating BPM devices by applying Lambertson's Method. A plan was made to minimize BPM measurement errors through applying the BPM electrical calibration method for BPM devices to be used by the PAL-XFEL. This paper examines the processes for checking the performance of the S-BPM installed in the PAL-ITF and the results of its measurements.

INTRODUCTION

The three main parameters that an injection testing facility should measure are charge, energy and emittance. Although ICT and FC were installed to measure charge, the noise generated in a klystron modulator not only interrupted accurate measurement but prevented low bunch charges under tens of pC from being measured. Due to the changes in the overall voltage level of PAL-ITF, integration of ICT measured value failed to maintain perfect accuracy in terms of methodology (measured value continuously changed by +/- 5pC). Accordingly, to solve the noise problems and accurately measure the quantity of electric charge, Turbo-ICT was installed.

Accurate measurement of beam positions requires not only BPM pickup characteristics but comprehensive methods of checking the BPM system, which can include all factors with potential BPM offset such as alignment in the process of installing cables, electronics and BPM equipment. To check sensitivity and offset of BPM, Lambertson's method was applied. The factors that should be calibrated to improve accuracy and precision are provided in Fig.1 [1][2]. See Fig.2 for types and locations of diagnostic units installed in PAL-ITF [3].

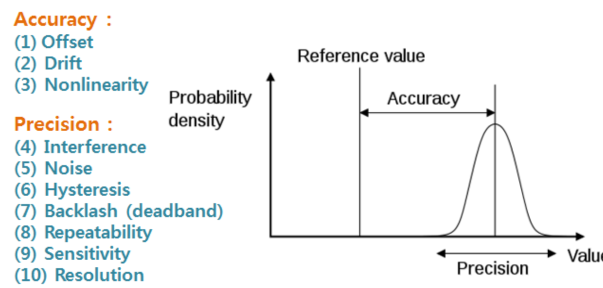

Figure 1: Factors crucial to improving the performance of diagnostic units.

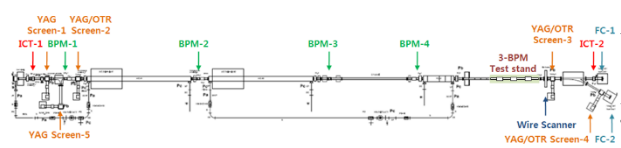

Figure 2: Types and locations of diagnostic units installed in PAL-ITF.

BEAM CHARGE MONITOR (BCM)

In PAL-ITF, instead of installing BCM-IHR-E electronics recommended by Bergoz Instrumentation, ICT output was going to be directly connected to an oscilloscope to measure quantity of electric beam charge, but noise prevented an accurate measurement. As shown in Fig.3, use of 50 ohm impedance matching and low-pass filter resulted in some improvement, but the klystron modulator led to constant slopping of ground-level voltage and measurement failed in low beam charge due to weak ICT output current.

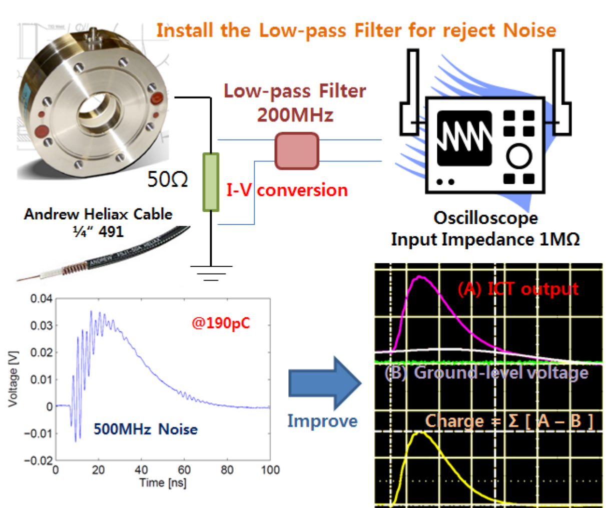

Figure 3: Improvement of ICT measurement methods.

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As a way to solve the noise problems and accurately measure the 1~200pC beam charge required by PAL-XFEL, Turbo-ICT, which was researched and developed for Swiss-FEL, was purchased and installed in PAL-ITF as a special BCM was necessary [4]. If a user provides service conditions including beam charge measuring ranges, noise state and two-bunch mode, a manufacturer can custom-make a Turbo-ICT and precisely calibrate it for supply [5]. According to the measurement of PAL-ITF's bunch charge using Turbo-ICT, noise problems generated in the klystron modulator could be solved and low bunch charge measurement of 1pC was possible, as shown in Fig.4.

Turbo-ICT input charge (pC)	BCM Out (V)
426,5501	3,640
307,9428	3,516
220,0240	3,384
152,2194	3,254
108,7602	3,140
78,3376	3,021
55,0136	2,886
39,3070	2,766
27,2251	2,645
19,6097	2,536
14,0110	2,414
9,6265	2,275
6,8781	2,161
4,9542	2,055
3,4274	1,930
2,4489	1,810
1,7178	1,685
1,2387	1,579
0,8851	1,477
0,6123	1,363
0,4375	1,260
0,3155	1,157
0,2198	1,064

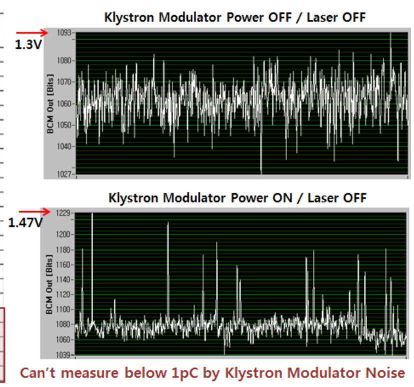

Figure 4: Problems of Klystron modulator noise and measured value of Turbo-ICT.

For XFEL bunch charge stability, BCM measured value controls the laser system through fast feed-forward control. The results of measuring three devices in the gearing of Turbo-ICT, laser system and BPM in PAL-ITF revealed that the laser system is likely to control charge stability, and measurement of charge using BPM Sum value is possible. See Fig.5 for Turbo-ICT following charge control by laser system and BPM Sum value measurement results.

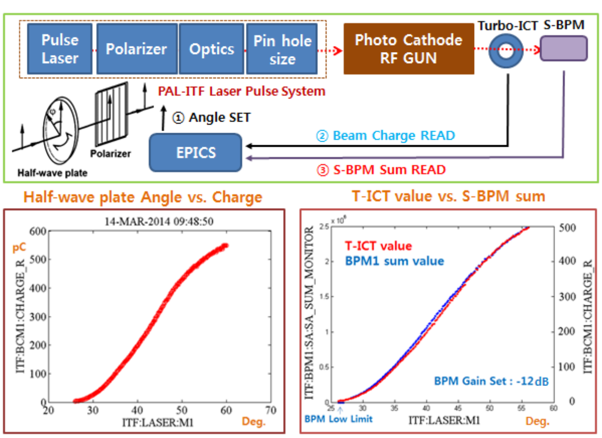

Figure 5: Turbo-ICT following charge control by laser system and BPM Sum value measurement results

An accurately measured charge by BCM can show where quantities of electric charge have been lost. As shown in Fig.6, it is planned to operate BCM measured value in line with the machine protection interlock (MPI) and personal safety interlock (PSI) system.

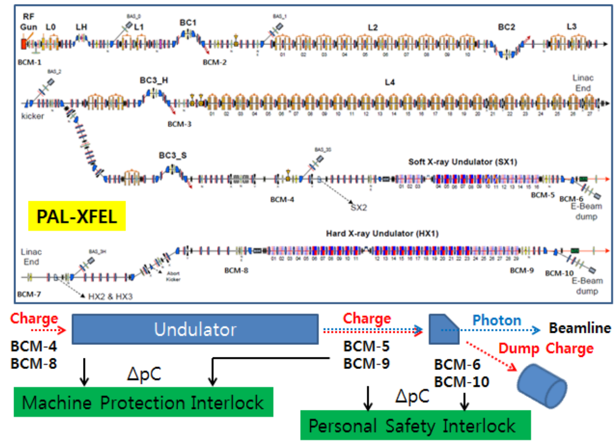

Figure 6: BCM's operation plan in line with MPI & PSI.

Mid-Energy Faraday Cup (FARC-04) measurement method produced by Radiabeam Technologies was improved as shown in Fig.7. However, as impedance unmatching problems occurred in the 0.5m thin cable connector which was used in installing Lead (Pb) block to shield radiation, reflection of FC signal and changes in ground level voltage created difficulties in measuring charge.

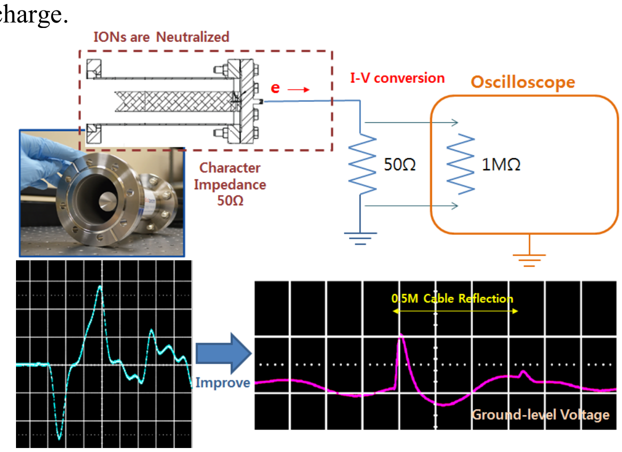

Figure 7: Faraday Cup measurement results.

STRIPLINE BEAM POSITION MONITOR (S-BPM)

See Fig.8 for ITF's S-BPM system employing Libera brillance Single Pass.

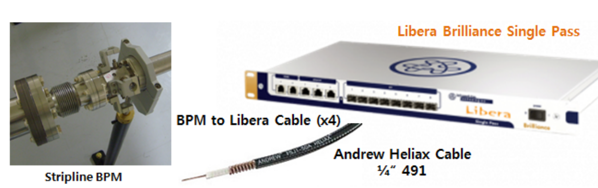

Figure 8: S-BPM system configuration of PAL-ITF

The physical concepts of electromagnetic field generated in beam bunch and BPM pickup are well known through several studies [6]. Of the BPM pickups designed and produced, poorly assembled pickups are

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sorted out at BPM Test-stand through testing [3]. However, measures should be devised to detect the many problems that can occur in installing BPM on a ITF site, including damage, installation alignment and cable connection.

To calibrate the sensitivity and offset of BPM pickup, three-step measurement was applied as shown in Fig.9. The findings through these steps included:

- Position offset of instruments generated in installing BPM;
- Sensitivity difference of BPM pickup and position offset affected by the length of cables (attenuation);
- Position offset affected by BPM electronics.

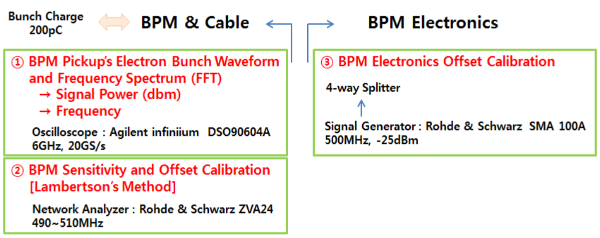

Figure 9: BPM Sensitivity & Offset test procedure.

Adjusting the internal offset in the BPM system is crucial to achieving perfect position accuracy [7][8]. Some parts of data measured by a measuring instrument in Fig.10 and Fig.11 and offset measurement results of S-BPM system are shown in Fig.12.

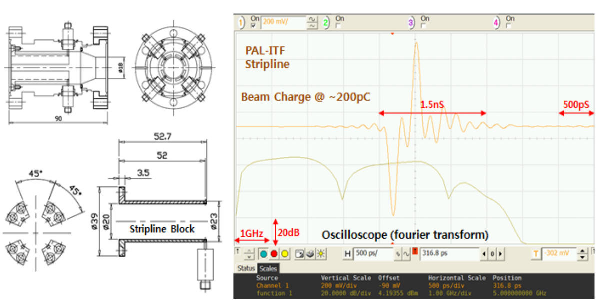

Figure 10: Signal of S-BPM Pickup.

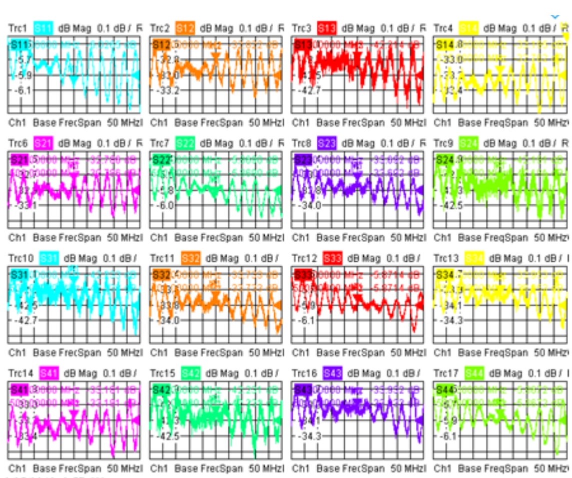

Figure 11: Sensitivity of S-BPM Pickup.

	Survey Alignment Measure mechanical offset	Libera electronics display center offset	Electrical center offset by Lambertson algorithm	Total Offset
X				
BPM1	-0.000	0.255	-0.028	0.283
BPM2	-0.300	0.090	-0.139	-0.071
BPM3	-0.819	0.195	0.200	-0.824
BPM4	1.433	0.190	-0.035	1.658
BPM5	-0.050	0.072	0.042	-0.020
Y				
BPM1	0.425	-0.105	0.077	-0.607
BPM2	0.150	-0.045	-0.344	0.149
BPM3	-0.607	-0.125	-0.092	0.574
BPM4	-0.497	-0.174	0.111	0.212
BPM5	0.220	0.210	0.316	-0.326

Figure 12: Offset of S-BPM.

With the assistance of an ITECH engineer (Dr. Matjaž žnidarčič), Libera Brilliance Single Pass was used in 3-BPM Test-stand to check the resolution of BPM system by beam charge. The results are shown in Fig.13. BPM resolution required by PAL-XFEL is 10 microns.

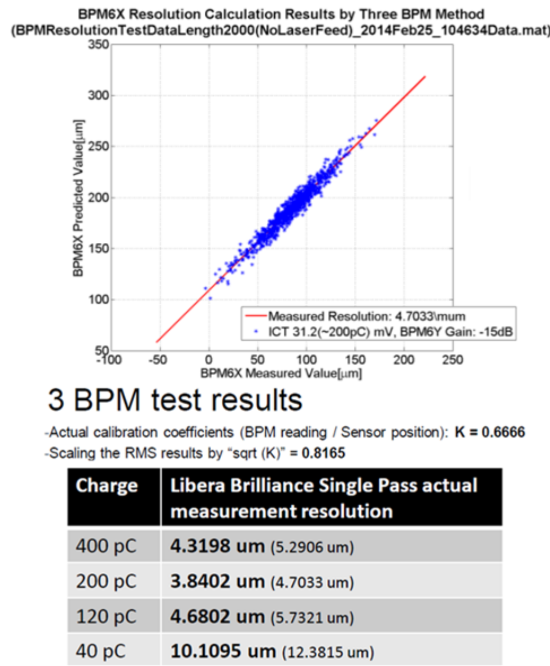

Figure 13: S-BPM resolution data.

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